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Testing Automatic Link Establishment High Frequency Radios Using Compact Disc Technology Part I: Clean Tones

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GLOSSARY

ALE: Automatic Link Establishment; a set of protocols defining the capability of an HF radio to link with another HF radio without operator assistance, under processor control.

allcalls: general broadcasts that do not request a response; can include automatic message display (AMD) messages.

anycalls: calls that request responses without designating specific addresses; can include link quality analysis and automatic message display calls.

automatic message display (AMD): short orderwire message using an expanded 64-character ASCII subset of the full 128-character ASCII.

clear channel: pure ALE tones with no degradations from noise, multipath, or fading.

command line arguments: arguments or parameters that are passed to the program; when invoking the program, they are typed after the program name at the computer prompt before pressing <ENTER>; in ALECALL, command line arguments include the filenames of input files and switches that invoke different modes of operation.

data text message (DTM): orderwire message transmissions that can be full ASCII or binary data; includes an acknowledgement request in the kd4 bit.

data word: the part of the basic ALE word that is described by the 3-bit preamble that precedes it; the data word consists of three 7-bit characters.

degraded conditions: the addition of noise, multipath, and/or fading, making the signal less clear.

group call: a call made to several stations without prearrangement.

interoperability: implies that two or more different systems, regardless of vendor, can effectively exchange information.

link quality analysis (LQA): used to rank channel quality; LQA is an exchange of information on the quality of the link between the radios, including bit error ratio (BER) and signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD).

NFM: noise, fading, or multipath (degraded tone) condition.

NFM parameters: input variables within the protocol file defining noise, fading, or multipath, set by the user as follows:

```
#
#a '*' defines a time delay or pause in integer Trw's (n * 0.392 s)
#a '!' defines total silence in integer Trw's (n * 0.392 s)
#
# $ SEQUENTIAL          # add Noise/Multipath in sequence it appears
#                       in the *.pro file; default: Multipath
#                       first, Gaussian noise second
$ INITIALIZE      0     # Random seed; range: 0-65535;
#                       default: 0 = use time of day
$ LEVELSCALE      0.25  # default: 0.25 for full program, 0.50 for
#                       Gaussian only program; range: 0.0 to 1.0
# fading
$ FADEBANDWIDTH   1.0   # Hz; default: 0.0; range: 0.1 to 10.0
# multipath
$ DELAY           .6    # ms; default: 0.0; range: 0.1 to 9.9
$ SCALINGRATIO    1.0   # default: 1.0; range: 0.1 to 1.0
# Gaussian noise
$ NOISEBANDWIDTH  3000  # Hz; default: 0; range: 200 to 9900
$ S/N             10    # dB; default:  99.9; range: -20.0 to +80.0
$ NFM             ON    # add degradation; default:OFF; range:ON, OFF
#
```

preamble: the part of the basic ALE word that describes the data word that follows; there are eight possible 3-bit preambles: THRU (represented by 001 in binary), TO (010), FROM (100), COMMAND (110), DATA (000), THIS IS or TIS (101), THIS WAS or TWAS (011), REPEAT (111).

protocol file: the first part of the ALE tone generation; it is the input file to ALECALL program; it represents the basic ALE call with an easily read and understood ASCII format; an ALE preamble with the accompanying data word is represented by one line of the ALE protocol file; the line also contains an L or R leading character designating whether this ALE word is to be recorded on the left or right channel of the sound file; the last item on a line of the protocol file is a number indicating how many times this ALE word will be repeated before the next ALE word begins; the pause or silence between ALE words is represented by a "*" (or a "!") and an integer; this integer represents the duration of the pause or silence in multiples of redundant word time (T_{rw}) of 392 ms.

sound file: the output of the ALECALL program, digitized at a sample rate of 44.1 kHz, in either wave format for the sound card, or digital audio (DA) format for the CD.

sounds: unilateral broadcast transmissions that are used by receiving stations to determine optimal channels.

star netcalls: a prearranged collection of member stations in a network.

T_{rw}: the transmission time for the three repetitions of the 49-bit ALE words, 392 ms.; redundant word time.

T_w: the transmission time for a single 49-bit ALE word, one-third of a T_{rw} ($1*T_{rw} = 3*T_w$) or approximately 130.7 ms; this unit is useful for calculating the wait times for replies and slotwidth times of the time slots in group calls.

time slot: the time allotted to a radio responding to a star netcall within which it must respond; the time slots are designated on the right channel of the test disc.

tone file: an octal representation of the ALE frequency tones (8-fsk modulation) that result from word encoding and interleaving, transmitted by the radio; the tone file is an output of ALECALL in normal mode. The tone file is also input to ALECALL in another mode to generate calibration files of one or more of the 8 ALE frequencies.

UUT: unit under test; the radio being tested in an interoperability test.

Testing Automatic Link Establishment High Frequency Radios Using Compact Disc Technology Part I: Clean Tones

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A method of high frequency (HF) radio interoperability testing in accordance with Federal Standards 1045A and 1046/1 is now available on a compact disc (CD) created by engineers at the National Telecommunications and Information Administration, Institute for Telecommunication Sciences. This report describes both the use of the CD and the software that created the sound files recorded on the CD. The sound files, which can be recreated by the program on a personal computer and played through a PC sound card, were recorded on a compact disc and packaged with the executable software for distribution to the public. The use of the CD for interoperability testing is explained, and tools are provided to simplify testing, such as data log sheets and additional utility software.

Key words: FED-STD-1045A; FED-STD-1046/1; automatic link establishment; ALE; interoperability; compact disc; CD; high frequency (HF) radio

1. OVERVIEW

Automatic Link Establishment (ALE) is a cornerstone in the growing trend of automation and ease in operation of high frequency (HF) radios. Federal Standard FED-STD-1045, the first in the family of automated and adaptive HF radio standards, and Military Standard MIL-STD-188-141A define minimum features required in an ALE radio procured by a U.S. Government agency. The goal of the U.S. Government is over-the-air interoperability for all agencies citing these standards in their procurement. The National Telecommunications and Information Administration, Institute for Telecommunication Sciences (NTIA/ITS) has conducted performance and interoperability tests on HF ALE radios. This testing typically has been a costly and time-consuming process. In an effort to simplify performance and interoperability testing, NTIAIITS has produced the first audio compact disc (CD) that implements standard reference tones of ALE radio calls. This production was in response to an HF Industry Association (HFIA) request for a “standard” test tape of tones that encodes key specific functions of the Government standards. In addition, a companion floppy

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computer disk provides listings of the protocols used in generating the CD. A prototype CD was provided free of charge in November 1993, to all members of the HFIA and interested U.S. Government agencies. The CD provides an easy-to-use and documented implementation of FED-STD-1045A and FED-STD-1046/1. Users of the CD provided suggestions for improving the CD and the standardized test procedures and protocols. The final version of the ALE Clean Tones CD (CD-01a) was produced in December 1994.

This document describes the background and gives an overview of the software method used to create the digital audio sound files for the CD. The primary software for producing the sound files is a DOS program written in "C" called ALECALL. Details of the software structure and use of the CD are in the Appendices. Appendix A includes several flowcharts that describe the software, including an ALECALL Structure Chart; logic flowcharts for several key modules; and the Data Flow Diagram. Appendix B contains all of the documentation from the computer floppy disk that accompanies the CD. The test plans, details of software use, and test setup are included in Appendix B.

The ALE Clean Tone audio compact disc and the tone files that make up the collection of audio sounds used for testing the FED-STD-1045A and FED-STD-1046/1 HF radios are copyrighted (c) 1994 by the U.S. Department of Commerce. This collection of tones, or audio information, is referred to as NIST Special Database 17.

2. BACKGROUND ON HF RADIOS AND ALE

Due to the automation and ease of operation of ALE radios, HF radio communications are now available to anyone, regardless of experience and training. The ALE HF transceiver has embedded computer-controlled sounding, channel scanning, and adaptive channel-selection techniques. These techniques are dictated by the variable HF propagation environment and formerly required an experienced radio operator. The task of operating an HF radio is much easier with ALE because channel selection, sounding, and scanning are automated. The soundings are used to rank the channel frequencies assigned to the radio. Each time a channel is evaluated, it is ranked based on signal strength and on recent past performance. Later, when the transceiver is placing a call, the channels are selected according to their respective rank until a link is established. This link is accomplished by a three-way handshake (Figure 1). Typically, an unoccupied ALE radio returns to the scan or listening mode. When it receives an initial call, it returns a response to the originating radio, which in turn sends back an acknowledgment, thus completing the link establishment.

Federal Standards define all of the protocols that comprise ALE radio operations. FED-STD-1045A describes the minimum ALE features required in an ALE radio procured by a Federal agency, such as single- and multiple-channel individual (station-to-station) calls and single- and multiple-channel sounding. Some optional features in FED-STD-1045A are required in FED-STD-1046/1 (Table 1). These features include orderwire link quality analysis (LQA), used to rank channel quality; orderwire message transmission such as automatic message display (AMD) for short orderwire ASCII

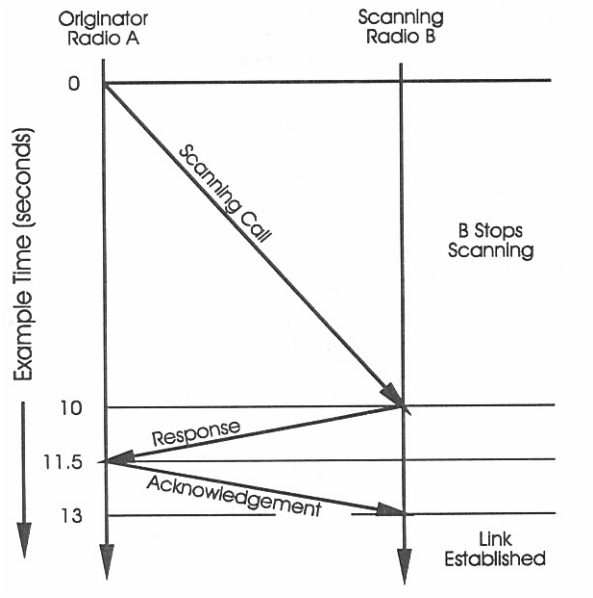

Figure 1. Example of a three-way handshake used by HF ALE radios to establish a link.

messages; data text message (DTM) for ASCII or binary data transmission; and cyclic redundancy check (CRC), which is used to assure data integrity on any form of message [1]. ALE radios also have the ability to link with multiple stations in prearranged groups, called star nets, or groups that have not been prearranged; these protocols are also defined in these standards.

3. HISTORY OF STANDARDIZED ALE TESTING

Federal agencies procuring HF ALE radios have used laboratory and field testing to ensure interoperability and performance of the units under test (UUT) as specified in the Federal standards. Interoperability implies that two different systems, regardless of vendor, can effectively exchange information. Testing the candidate radios to verify that they meet the mandatory requirements of FED-STD-1045 and FED-STD-1046/1 ensures that all of the ALE radios purchased by a Federal agency will interoperate. Unfortunately, testing has typically been an arduous and costly process.

The interoperability testing and performance evaluation techniques initially used by the Government were complex and required transporting either test equipment to the manufacturer's location, or the radios to the Government laboratories and field test sites. After rigorously checking the functionality of two identical systems, the probability of linking was measured in the lab under various simulated atmospheric conditions using portable, narrowband, propagation channel simulators (Watterson model; [2]). Because performance is measured between two radio systems and because the ALE protocol uses the three-way handshake, two identical HF propagation channel simulators were required for this phase of the testing. Vendors were required to demonstrate over-the-air interoperability with the other vendors' radios at various sites to complete the testing process [3].

Table 1. Summary of the Basic Functions of the FED-STD-1045A Family of HF ALE Radio Standards (M = Mandatory, O = Optional, Blank = not addressed)

Functions	FS-1045 1/24/90	FS-1045A 10/18/93	FS-1046/1 & proposed FS-1046, Sections				
			1 10/93	1A	2	3	4
INDIVIDUAL CALLS							
Single Channel	M	M	M	M	M	M	M
Multiple Channel	M	M	M	M	M	M	M
SOUNDING							
Single Channel	M	M	M	M	M	M	M
Multiple Channel	M	M	M	M	M	M	M
ORDERWIRE - LQA							
LQA - SINAD	O	M	M	M	M	M	M
LQA - BER	M	M	M	M	M	M	M
LQA - Multipath				M	M	M	M
ORDERWIRE - MESSAGES							
AMD	M	M	M	M	M	M	M
CRC	O	O	M	M	M	M	M
Message - DTM: Basic & Extended	O	O	M	M	M	M	M
Message - DBM: Basic & Extended	O	O	O	M	M	M	M
MULTIPLE STATIONS							
Star Net	M	M	M	M	M	M	M
Star Group		O	M	M	M	M	M
Allcalls	M	M	M	M	M	M	M
Anycalls		O	M	M	M	M	M
Multipoint Net				M	M	M	M
Multipoint Group				M	M	M	M
Wildcard Calls			M	M	M	M	M

These interoperability tests must be performed more than once in some cases. As each new adaptive radio standard is issued, at least two more sets of tests must be performed: proof-of-concept testing prior to the release of the Standard and interoperability and performance testing. Although the Standards were intended to describe basic ALE requirements, some functions were interpreted differently by the vendors. Thus, two radios from different vendors, each allegedly complying with the Standard, may not interoperate due to subtle differences in implementation.

After the first testing for Government procurement was performed in 1990, a need for improved, standardized testing was recognized [4]. A standardized test media could facilitate the testing process and clearly illustrate expectations for an ALE radio procured by a Federal agency. This need prompted the High Frequency Industry Association (HFIA), in conjunction with the Armed Forces Communications and Electronics Association (AFCEA), to propose twelve types of tests that cover all of the mandatory features of the two Government ALE radio standards (Federal and Military). The HFIA proposed that a Government agency create a standardized tape or audio compact disc that would support all of the suggested tests. Since the standards also specify performance requirements, the test plan included procedures for using both high quality clear channel tones and degraded tones (that would occur due to noise, multipath, and fading). The degraded tones would simulate ionospheric propagation conditions as defined by the International Radio Consultative Committee (CCIR) Recommendation 520-1 [5,6].

The format for a standardized test includes all the mandatory and optional features in FED-STD-1045 and mandatory features in FED-STD-1046/1 (Table 2; [1]). The HFIA-suggested test plan was modified and adopted by the Federal Telecommunication Standards Committee (FTSC) and is included in Appendix B. The ALE features to be tested are:

1) Sounds—unilateral broadcast transmissions—are used by receiving stations to determine optimal channels. The test plan calls for various combinations of characters to form the sounder's address.
2) Allcalls—general broadcasts that do not request a response—include both simple allcalls, with and without automatic message display (AMD) messages, and selective allcalls to demonstrate proper and improper addressing.
3) Individual calls—calls made to specific addresses—include LQA and AMD. The LQA is an exchange of information on the quality of the link between the radios and is used by the radios to rank the channels. This information includes bit error ratio (BER), the ratio of errored bits to received bits, and signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD).
4) The ALE standard also requires the capability to set up a prearranged collection of member stations in a network. These star netcalls consist of simple calls and calls with LQA and AMD.
5) A group call is a call made to several stations without prearrangement and is tested as are star netcalls. In the same manner, anycalls—calls that request responses without designating specific addresses—are tested as simple, LQA and AMD calls, and also include calls to demonstrate proper and improper addressing.
6) Wildcard calls—calls made using an address with one or more of the special wildcard character (the "?" symbo1)—are tested with three- and six-character-length addresses [7].

Table 2. HFIA-suggested Format for a Standard Test Tape or CD

Section	Type of Call	Comments
1	Sounds	Many addresses using all characters in the allowed set
		Noise added at three signal-to-noise levels for a selected address
2	100 Quick Sounds	Mix of long and short addresses
3	Allcall	Simple and with AMD
4	Selective Allcall	With known and foreign address
5	Individual Calling	With four levels of LQA in acknowledgement
6	Star Netcalls	Simple and with LQA and AMD
7	Star Group Calls	Simple and with LQA and AMD
8	Anycalls	Simple and with LQA and AMD
9	Selective Anycalls	With known and foreign address
10	Wildcard Calls	With length of three and six characters
11	AMD	90-character message in response section of a call
12	Performance Tests with Allcall & AMD	100 calls for each of the 12 sets of conditions in FED-STD-1045 matrix

4. USING AUDIO CDS FOR INTEROPERABILITY TESTING

The “clear channel” test CD contains all of the calls described in the above section. The HFIA-suggested test plan is the basis for the functions implemented on the audio CD test disc, described herein. The development of a standardized test disc greatly facilitates the interoperability and performance tests. This inexpensive test disc allows U.S. Government agencies and HF radio developers and vendors to test and verify HF radio interoperability and compliance with the Federal standards using a common set of reference tones.

Traditionally, a radio has demonstrated interoperability by first successfully accepting, as the receiving radio, all of these test calls from a standard ALE radio (transceiver and ALE controller) and then by reversing the process and correctly transmitting the same calls to a standard radio. To use the ALE CD, a CD with a transceiver is substituted for the ALE controller in the first part of the testing process. The performance tests are completed by executing a simple call 100 times for each condition of clear channel and the suite of degraded channel conditions of noise, multipath, and fading. The probability-of-linking statistics are compiled from this suite of 100 calls.

The ALE waveform consists of an 8-ary frequency-shift keying (FSK) modulation containing eight orthogonal tones, each of which represents three bits of data. The bits are first encoded and interleaved to constitute a word; this word is 8-ary FSK modulated, transmitted, and then decoded at the receive station. A computer program emulates an ALE radio by encoding the various calls into ALE tones [8]. The ALE tones are located on the left stereo channel of the CD; timing, example responses, and verbal information to assist the test operator are on the right channel. When testing ALE radios in the laboratory, a transmit radio and a receive radio are required. The ALE tone files can be played through an ordinary audio CD player, replacing the ALE controller in the first phase of the laboratory testing. The ALE tone files may also be played through a sound card on a PC; this is discussed in Appendix C.

The ALE tones are sent, after impedance-and level- matching, through the microphone input (VOX) line of an HF radio transceiver (Figure 2). The right channel is played through an audio amplifier and speaker. Radio #2 transceiver antenna port output is passed through a 50-ohm RF load and attenuators into radio transceiver #1. The signal, which can be fed through the HF channel simulator for degraded ionospheric propagation conditions, is received by the ALE Controller #1, the UUT. If the signal is not degraded by the channel simulator, then the resulting clean tones can be used to ascertain the receive/decode level of interoperability of the UUT. Degraded ionospheric propagation conditions, either digitally added to a test CD or added with an HF channel simulator, test the

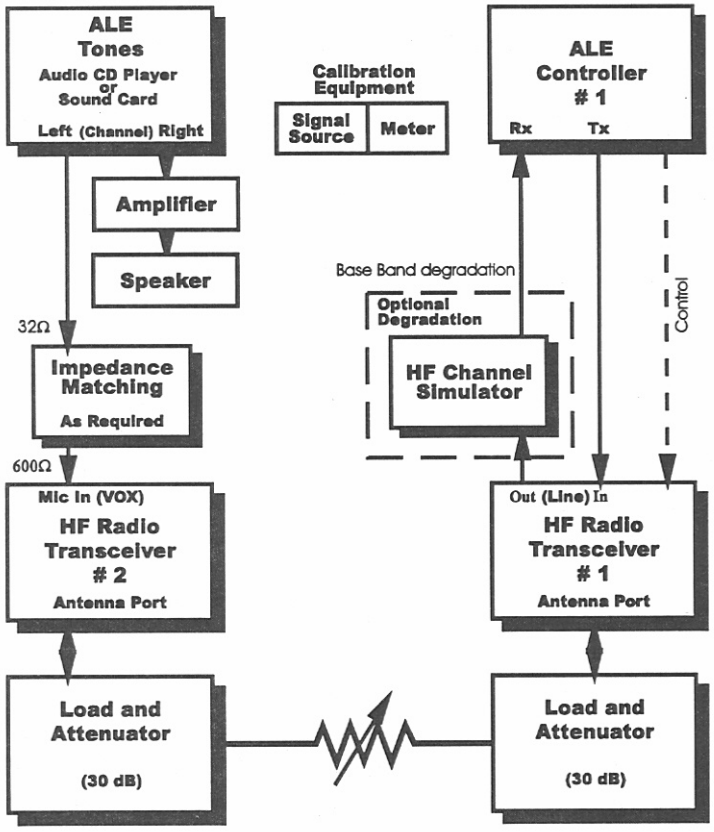

Figure 2. Equipment setup for one-way radio testing.

performance of the radio under adverse conditions. In this manner, a CD can be used for both interoperability and performance testing. The test calls, thus automated, can be consistently repeated as needed. If the UUT can indicate linking status, and if the CD player is set in repeat mode, then tedious and repetitious testing can be automated.

Interoperability testing cannot be performed completely using an audio CD because the CD player is a one-directional device. It will continue to play the proper responses and acknowledgements regardless of whether it is sent a correct signal. Thus, it can only be used to test the receive functions of an HF ALE radio, in the first phase of testing. Transmit functions are tested in the second phase, after the receive functions are successfully tested (Figure 3). The transmit function tests repeat the first phase tests and must be executed by another UUT radio that is substituted for the CD player/radio module. The UUT that has completed the receive tests would remain in place and receive the same calls as in the first phase, this time transmitted by the second UUT. Thus the CD test disc serves as a representation of the Federal standards for the first phase of interoperability testing. The digitally recorded tone files greatly improve the testing procedure by defining and clarifying the Federal standards, and by offering a consistent, easily repeatable and inexpensive test medium.

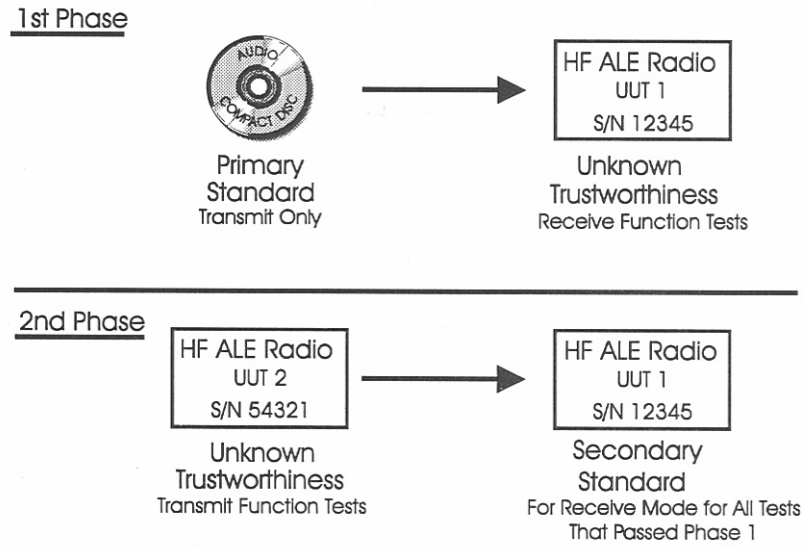

Figure 3. Two-step process for interoperability testing with an audio CD.

5. METHOD OF GENERATING TEST FILES

Because it is not feasible to manually decipher the digitally recorded ALE sounds or binary representations in the sound file, it is essential that the method of generating the ALE tone test files includes a complete audit trail of input protocol, encoded tones, and the output sound file tones. Three files are used to track the operation of the program that generates the calls (Figure 4):

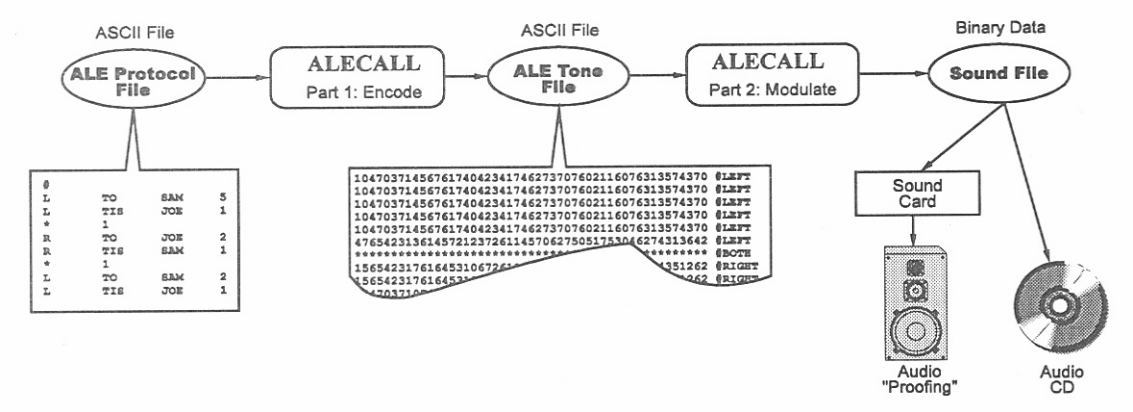

Figure 4. Software technique for generating sound files that contain ALE tones.

1) The ALE protocol file: the actual ALE words defined in FED-STD-1045.
2) The ALE tone file: an octal representation of the ALE frequency tones transmitted by a radio; they are the result of the word-encoding and interleaving.
3) The sound file: the resultant sounds digitized at a sample rate of 44.1 kHz, in either wave format for the sound card, or digital audio (DA) format for the CD.

This three-part process has been developed as a computer program, "ALECALL," at NTIA/ITS. This program created the sound files for the first "clean tones" CD Beta test disc (recorded in August 1993) and the final version CD-01a Clean Tones Disc. The program also can add degraded channel conditions to the test calls to indicate radio performance.

The basic ALE call is represented by an ALE protocol file in ASCII format that is easy to understand. The basic ALE word consists of a 3-bit preamble and a data word of three 7-bit characters, resulting in a total of 24 bits. There are eight possible preambles, such as TO (represented in binary by 010), FROM (100), COMMAND (110), and DATA (000) that describe the data word. A preamble with the accompanying data word appears as one line of the ALE protocol file (Figure 4). This line begins with an L or R, designating whether this ALE word is recorded on the left or right channel of the sound file. The line ends with a number indicating how many times this ALE word will be repeated before the next ALE word begins. A pause or silence between ALE words is represented by a "*" (or a "!"). An integer value of the duration in redundant word time (T_{rw}) is also included (1 T_{rw} = 392 ms). This ALE protocol file is the input to the ALECALL program that encodes the ALE words as described in FED-STD-1045A and produces the tone file and the sound file.

During an ALE radio call, each ALE word is divided into two 12-bit halves. These are Golay-encoded into two 24-bit words and are interleaved to form a 48-bit word. An additional stuff bit is added to produce a 49-bit word. This word is transmitted three times to overcome the effects of environmental conditions. The transmission time for the three 49-bit words is 392 ms, or one T_{rw}.

The receiving station then performs a 2-out-of-3 majority vote, bit by bit on the three redundant words, and completes the decoding process.

The ALECALL program, using the ALE encoding modules from the HF Automatic Link Establishment Simulator program [5] encodes each ALE word as described above. The three 49-bit ALE words, when converted into octal format, represent the ALE 8-ary FSK frequencies since each of the eight ALE tones represents 3 bits of data. These 49 octal digits are recorded in an ASCII ALE tone file as part of the audit trail created by the program (Figure 4). Also recorded is the channel designation: right, left, or both. Periods of silence are represented in the tone file by a "*". A radio responding to a star netcall must respond within a designated time slot, as described in FED-STD-1045. The right channel of the test disc has time-ticks that mark the slot width times for the ALE netcall responses. Using these time-ticks, the test operator can determine if the UUT responded to the Star netcall during the correct time slot, as defined by ALE protocols in FED-STD-1045A. A "T" designates a time-tick in the tone file, followed by the appropriate number of asterisks (*) for silence. This tone file, created by the ALECALL program, records this additional information on the right channel. The tone file also records the ALE tone representation of the call on the left channel and, as such, is a frequency representation of the modulation that an ALE radio would make.

Sound files, created from the tone files, can be played either through a sound card or a CD player. Each ALE tone transmission is 8 ms long (a transmission rate of 125 tones per second). Since each ALE tone represents 3 bits, the transmitted bit rate is 375 bps. The standard sampling rate of a CD is 44.1 kHz, so each tone is represented by a cosine wave of approximately 353 samples. The elapsed time, used to calculate the cosine waves, facilitates the smooth transitioning between the 8-ms frequencies. The sample values of the cosine waves, with 16-bit sampling, can range from $+[2^{15} - 1]$ to $-[2^{15} -1]$. The time-ticks, which mark the star netcall slot widths, sound like a noise pop on the CD. The ticks are created with a 8-ms duration, 1000-Hz signal followed by silence to fill the slot-width duration.

The ticks can also be produced another way, demonstrated by the following example. Files were prerecorded of an ITS staff member speaking each number from 1 to 16 and a few words such as "start" and "stop." Instead of inserting the 8-ms duration, 1000-Hz noise pop, the appropriate word or number was added in each slot. Thus, "start" was recorded in slot 0, "one" in slot one, "two" in slot two, and so forth to the last slot. Each sample, whether a tick, a cosine wave or silence, was written to the sound file in binary format.

The wave file played through a sound card has been an invaluable tool for software development and demonstrations at the NTIA/ITS laboratories. Any ALE call can be created and tested in a few minutes. Questions on radio functions can be instantly tested and answered. As Federal standards are interpreted and implemented through the protocol file, the call can be created and perfected quickly and easily. Using commercially available software, the wave files or parts of the wave files can be visually examined and analyzed with such tools as the Fast Fourier Transform (FFT). The ALECALL software could also be used by developers to create test calls as needed. As a further aid to industry, NTIA/ITS released in 1994 the floppy disk containing the ALECALL executable

software, also available to the public via the internet. Thus industry has a valuable development tool for prototyping new features that may be incorporated into later issuances of the Federal and Military standards. All of the documentation files that support use of ALECALL and CD-01a are in the Appendices and are described in Table 3.

Table 3. ALECALL Documentation Files from the CD-01A Companion Floppy Disk

Documentation Title	Floppy Disk Filename	Appendix	Purpose
FTSC Test Plan for Interoperability and Performance of ALE Radios	ftip-man.*	B	the basis of the project
Appendix I to ALE Test Plan - Suggested Format of Standard Test Audio Compact Disc	ftip-ap1.*	C	modified and implementable adaptation of the FTSC Test Plan; directly corresponds to tracks on CD-01a
Appendix II to ALE Test Plan - Log Sheets for Recording Test Data When Using the Standard Test Audio Compact Disc	cdlog01a.xls, cdlogx.xls, sounds.xls, read-log.txt	D	provided to facilitate testing with CD-01a; they directly correspond to the disc
Audio Compact Disc Layout to Implement the HF Radio Test Plan	cd-layout.*	E	shows the CD track listing
CD-Info Information for Users of the ALE Clean Tones Compact Disc 01a	cd-info.*	F	explains the software usage and the protocol files that are read by the program to determine the ALE call parameters; test equipment setup is also outlined
ALE Clean Tones on Compact Disc 01a	readme.1st	F	describes all of the files on the floppy disc
Calculations for Slot Widths on Compact Disc 01a	slotwdth.wp5	F	worksheet for calculating the slot widths for net and group calls
Narration for Track 1 on the Audio CD	cd-intro.wp	G	text of CD Track 1 narration
How To Receive ALECALL Software Package Via FTP	readme.too	H	contains instructions for the Anonymous FTP of the software
Request for NTIA ALE Software and Documentation	ale-wan2.*	H	used by ITS personnel to track software requests
Evaluation Form for NTIA Audio Compact Disc 01a	evaluate.*	I	a form for software and CD suggestions and comments

* Indicates a file that is available under three file types and extensions: .wp for Word Perfect files, .ps for PostScript files (or .eps for Encapsulated PostScript), and .txt for ASCII files.

Instructions for obtaining the software are included in Appendix H. Basic program operations and specific information on the protocol and tone file formats are described in Appendix F, CD-INFO Information for Users of the ALE Clean Tones Compact Disc 01a.

6. INITIAL TESTING

The Beta version of the clean tones ALE test CD was distributed to various vendors and Government agencies in November 1993. Most of the Beta test users were enthusiastic about the possibilities of using an audio CD for testing. A clear example of how all the basic functions of an ALE radio are expected to perform is now available to all vendors through the CD.

Initial use and analysis uncovered a few errors in the Beta release; some were protocol file errors in the creation of the CD and were easily corrected on the final release in December 1994. Some of the errors, however, indicate problems with either the HFIA-suggested test plan or with the vendors' interpretation of the Federal and Military standards. Some of these problems required consensus by the HFIA user community on the correct protocol. Others had to be resolved by the FTSC. Thus, the ALE Clean Tones CD-01a was instrumental in both the transfer of technology to industry and in fine-tuning the Government standards.

The ALECALL program has also been used successfully in the laboratory to quickly analyze an apparent interoperability problem uncovered by a Federal agency. The agency was testing two different brands of HF ALE radios. They discovered that after linking between the two radios the first brand (vendor X) could send an AMD message to the second brand (vendor Y), but vendor Y could not send the AMD message to vendor X. Using the ALECALL program through a sound card on a PC, NTIA/ITS personnel created a suite of tests to analyze the various implementations of AMD messaging used by the vendors. Eight different calls were created, each testing a slightly different protocol variation in an ALE AMD call. It was discovered that one of the ALE radios had implemented a required feature of the standard, while the other radio had not. This resulted in two different implementations of AMD messaging and noninteroperability for that specific function. The ability of a laboratory to quickly recreate each of the vendors' protocol implementations and pinpoint the exact nature of the problem demonstrates the power and value of the ALECALL software in the laboratory.

7. SUMMARY AND FUTURE DIRECTIONS

The Federal standards for HF ALE radios specify expected linking performance under simulated atmospheric conditions of Gaussian noise, and CCIR Good and Poor channels at various signal-to-noise ratios. CCIR Good is defined as a fading bandwidth of 0.1 Hz and a multipath delay of 0.5 ms; CCIR Poor has a 1.0-Hz fading bandwidth and a 2.2-ms multipath delay (modified from CCIR Recommendation 520-1) [6]. Both are invoked at various Gaussian signal-to-noise ratios. The next iteration of the ALE test CD will incorporate signal degradation caused by noise, multipath, and

fading using the Watterson channel model [2]. A simple ALE call will be repeated under the matrix of simulated atmospheric conditions. A set of 12 CDs, one for each atmospheric condition at a given signal-to-noise ratio, will be produced; each CD will have 100 calls. With these CDs, a vendor that cannot afford to purchase an expensive propagation channel simulator can test HF ALE radio performance under the degraded conditions specified in the Federal standard. The techniques used to produce CD-01a could also be used to create tests with other ionospheric models.

NTIA/ITS periodically conducts radio interoperability and performance tests of HF ALE radios using the Federal standards. The ALE test CD is currently being used on a supplemental basis with these tests. As the viability of the test results from the CD is demonstrated, it is expected that the CD will be utilized for a major portion of this testing.

The ALE test CD is a versatile, inexpensive tool that has already proven to be invaluable in testing ALE radio interoperability and performance in accordance with the Federal standards. Developers and purchasers of ALE radio equipment now have a clear, primary standard for uniformly evaluating HF radios. The ALECALL software is an equally useful tool in ALE radio development. The software can be used to interpret and implement new and proposed ALE features. Using either the CD or the software, the features of the ALE Federal standards can be demonstrated easily and quickly. NTIA/ITS, through the CD-01a and the ALECALL software, has made the Federal standards, and thus, the Federal procurement process, available to all HF ALE radio vendors and operators.

8. ACKNOWLEDGMENTS

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